

GAS PURIFYING SYSTEM, GAS PURIFYING METHOD AND
DISCHARGE REACTION APPARATUS UTILIZED FOR GAS
PURIFYING SYSTEM

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BACKGROUND OF THE INVENTION

Field of The Invention

The present invention relates to a gas purifying system
or facility and gas a gas purifying method for purifying an
10 object gas to be purified by removing adverse or harmful
material or substance such as particulate mater and nitrogen
oxide contained in the object gas. The present invention also
relates to a discharge reaction apparatus utilized for the gas
purifying system or method mentioned above.

15 Relevant Art

In a conventional art, there are known some gas
purifying systems or facilities for purifying an exhaust gas
discharged from an engine or like by removing particulate
matter or material (PM), nitrogen oxide (NOx) and the like
20 contained in the exhaust gas.

For example, there is known a gas purifying system for
removing the PM, in which a particulate matter (PM) removing
filter is arranged in a gas flow path through which the exhaust
gas containing the PM flows to thereby trap or catch the PM.
25 Then, burnable material such as carbon contained in the PM
trapped by the PM removing filter is burned and then removed,

and thereafter, the PM removing filter is regenerated in function. Such gas purifying system is disclosed in Japanese Patent Laid-open (KOKAI) Publication No. HEI 11-062558.

On the other hand, there is also known a gas purifying system for removing the NO_x, in which a three way catalyst which reduces and decomposes the NO_x is arranged in a gas flow path through which an exhaust gas containing the NO_x flows. Such three way catalyst carries noble metal such as Pt for activation. Such gas purifying system is disclosed in Japanese Patent Laid-open (KOKAI) Publication No. 2002-045701.

In the gas purifying system for removing the PM such as disclosed in Japanese Patent Laid-open (KOKAI) Publication No. HEI 11-062558, it is required to heat the gas at a temperature of about 600°C for removing carbon or like material contained in the PM caught by the PM removing filter through the combustion reaction with oxygen.

On the other hand, in the gas purifying system for removing the NO_x such as disclosed in Japanese Patent Laid-open (KOKAI) Publication No. 2002-045701, a reduction catalyst attains its function generally at a temperature of more than about 300°C. At a temperature of less than 300°C of the exhaust gas, the catalyst is less activated and the NO_x will be not able to sufficiently reduced and decomposed. Moreover, harmful dinitrogen monoxide (N₂O) will be generated during the reduction and decomposition process of the NO_x.

Therefore, in both types of the gas purifying systems of the prior art mentioned above, an external heater or like as a heating source for heating the exhaust gas is required to be equipped with. In addition, in a case where the exhaust gas is of a low temperature (especially, less than 200°C), the PM and/or NOx cannot be effectively and sufficiently trapped and removed.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to substantially eliminate defects or drawbacks encountered in the prior art mentioned above and to provide a gas purifying system and a gas purifying method capable of effectively removing particular matter and harmful substance such as nitrogen oxide from an object gas to be purified at a low temperature without heating the gas to thereby purifying the object gas.

Another object of the present invention is to provide a discharge reaction apparatus utilized for such gas purifying system as mentioned above to effectively remove the particular matter and harmful substance.

These and other objects can be achieved according to the present invention by providing, in one aspect, a gas purifying system for purifying an object gas comprising:

a gas flow line through which the object gas to be purified flows from an object gas generation mechanism;

a discharge reaction device provided on a way of the gas flow line;

a filter member disposed in the discharge reaction device having a structure for trapping particular matter contained in the object gas during a time when the object gas passes through the filter member; and

a discharge generation device operatively connected to the discharge reaction device for causing electric field inside the discharge reaction device and generating discharge plasma therein.

In preferred embodiments of this aspect, the filter member may have various structures such as a block structure composed of a plurality of packed solid materials, a block structure composed of fibrous material, a honey-comb structure, or monolith structure.

The filter member may also be composed of a dielectric material having dielectric constant of not less than 3, such as a ceramics.

The gas purifying system may further include an oxidizing catalyst disposed inside the discharge reaction device for oxidation combustion of the particulate matter.

The gas purifying system may further include an oxidizing catalyst arranged to the gas flow line at at least one of upstream side and downstream side of the discharge reaction device with respect to the object gas flow.

The gas purifying system may further include a

photocatalyst disposed inside the discharge reaction device so as to be activated by a discharged light.

The filter member may be provided with a reduction decomposition catalyst for reducing and decomposing nitrogen oxide contained in the object gas.

The gas purifying system may further include a hydrocarbon adding or applying device disposed to the gas flow line on the upstream side of the discharge reaction device so as to apply gaseous hydrocarbon to the object gas flowing through the gas flow line. The gaseous hydrocarbon is formed by gasifying solid or liquid state hydrocarbon by the hydrocarbon adding device.

The gas purifying system may further include a catalyst reaction unit provided at the gas flow line on a downstream side of the discharge reaction device for reducing and decomposing nitrogen oxide contained in the object gas.

The gas purifying system may further include a hydrocarbon adding device disposed to the gas flow line on the upstream side of the discharge reaction device so as to apply gaseous hydrocarbon to the object gas flowing through the gas flow line. The gaseous hydrocarbon is formed by gasifying solid or liquid state hydrocarbon by the hydrocarbon adding device.

The discharge reaction device has an outer cylindrical casing to which a connector is provided, and said discharge generation device includes a high voltage pole side connected to the connector through a cable, an electrode rod disposed

inside the filter member and connected to the connector through a cable, and an earth pole side connected to a portion of the outer casing of the discharge reaction device, which functions as an earth electrode.

5 In a modified aspect of the present invention, there is provided a gas purifying system for purifying an object gas comprising:

 a gas flow main line through which the object gas to be purified flows from an object gas generating mechanism, said
10 main gas flow line having a switching portion from which a plurality of gas flow branch lines extend;

 a plurality of discharge reaction devices each provided at an intermediate portion of each of the gas flow branch lines;

 a filter member disposed in each of the discharge
15 reaction devices having a structure for trapping particular matter contained in the object gas during a time when the object gas passes through the filter member;

 a discharge generation device operatively connected to each of the discharge reaction devices for causing electric field
20 inside the discharge reaction device and generating discharge plasma therein; and

 a switching means arranged for the switching portion formed to the gas flow main line for selectively switching the gas flow branch lines.

25 In this aspect, the plurality of gas flow branch lines are combined at a portion of the gas flow main line on the

downstream side of the discharge reaction devices.

In another aspect of the present invention, there is provided a gas purifying method of purifying an object gas comprising the steps of:

5 arranging a discharge reaction device, provided with a filter member, on a way of a gas flow line through which the object gas including particular matter to be treated flows;

 trapping particular matter in the object gas by the filter member; and

10 generating an electric field in an area in which the filter member is disposed and generating a discharge plasma in the discharge reaction device.

In a further aspect of the present invention, there is provided a discharge reaction apparatus comprising:

15 a cylindrical discharge reaction device;

 a filter member disposed inside the discharge reaction device; and

 a high voltage pole side and an earth pole side between which said filter member is arranged.

20 According to the structures and/or characters of the present invention mentioned above, the object gas to be purified by trapping and removing the particular matter (PM) and harmful substance from the object gas to be purified without heating at low temperature.

25 Moreover, the NO_x reduction decomposition at a low temperature can be performed without heating, in addition to

the PM trapping and combustion treatment, by adding reduction decomposition catalyst.

The nature and further characteristic features will be made more clear from the following descriptions made with
5 reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

Fig. 1 is a schematic view showing an arrangement of a
10 gas purifying system according to a first embodiment of the present invention;

Fig. 2 A is a longitudinal partial sectional view, in an enlarged scale, of a discharge reaction device of the first embodiment of Fig. 1, and Figs. 2B to 2D are sectional views of
15 a filter member of the gas purifying system of the present invention;

Fig. 3 is a chart showing reduction decomposition of NO_x in the discharge reaction device;

Fig. 4 is a graph representing a relationship between NO_x
20 lowering amount and a temperature of an object gas to be purified at a time when the NO_x contained in the object gas includes 15 vol% of oxygen;

Fig. 5 is a graph representing a relationship between NO_x lowering amount and a temperature of an object gas to be
25 purified at a time when the NO_x contained in the object gas includes 1 vol% of oxygen;

Fig. 6 is a graph representing a relationship between by-product amount of N_2O and a temperature of an object gas to be purified at a time when the NO_x contained in the object gas includes 1 vol% of oxygen;

5 Fig. 7 is a schematic view showing an arrangement of a gas purifying system according to a second embodiment of the present invention;

Fig. 8 is a schematic view showing a first modification of the gas purifying system of the second embodiment of Fig. 7;

10 Fig. 9 is a schematic view showing a second modification of the gas purifying system of the second embodiment of Fig. 7;

Fig. 10 is a schematic view showing a third modification of the gas purifying system of the second embodiment of Fig. 7;

15 Fig. 11 is a schematic view showing an arrangement of a gas purifying system according to a third embodiment of the present invention;

Fig. 12 is a schematic view showing an arrangement of a gas purifying system according to a fourth embodiment of the present invention;

20 Fig. 13 is a schematic view showing an arrangement of a gas purifying system according to a fifth embodiment of the present invention; and

Fig. 14 is a schematic view showing an arrangement of a gas purifying system according to a sixth embodiment of the present invention.

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DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of a gas purifying system and a gas purifying method, utilizing a discharge reaction device or apparatus, for the gas purifying system according to the
5 present invention will be described hereunder with reference to the accompanying drawings.

Referring to Fig. 1, showing a first embodiment of the gas purifying system according to the present invention.

The gas purifying system 1 includes a discharge reaction
10 device 4 provided on the way of a gas flow line or path 3 extending from an object gas generating mechanism 2, and a filter member or structure 5 disposed in a reaction container 4a of the discharge reaction device 4. The filter member 5 has a structure permitting an object gas X to be purified (merely
15 called hereinlater object gas) to flow through the inside thereof and having particulate matter trapping structure and function for trapping PM (Particulate Matter) and/or a harmful substance included in the object gas X.

Specific examples of the object gas generating
20 mechanism 2 are of an in-vehicle diesel engine and gasoline engine such as automotive engine, a vehicle generator drive motor and a ship propulsion motor and the like; the diesel engine and gasoline engine to generate power that are mounted on a movable body such as vehicle, ship and aircraft and the
25 like; and the fixed diesel engine and the gas engine (gas motor) used for co-generation (electro-thermal provision) system and

the power generation system.

These object gas generating mechanisms 2 use heavy oils, such as, A-heavy oil, C-heavy oil and the like, light oil, gasoline, city gas, methane, and propane, and discharge exhaust gasses that are called as the object gas X in the present invention.

Further, a discharge generating power source (discharge generation device) 7 is connected to the discharge reaction device 4 via an electric cable 6. The voltage application from this discharge generation device 7 causes discharge plasma to be generated at the discharge reaction device 4, while, the PM is trapped within the filter member 5 in accordance with electrical dust collecting function by an electric field generated. Further, radical oxide such as O, OH and O₃ and the like are formed by the discharge plasma, and the trapped PM is burned through oxidation of the radical oxide. Then the trapped PM is changed into CO₂ through a combustion treatment.

Fig. 2A is a schematic longitudinal section showing the gas purifying system 1, particularly, discharge reaction device 4.

For instance, cylindrical discharge reaction device 4 is arranged on the way of the tubular gas flow line 3. Further, for instance, block shaped filter member 5 is provided within the discharge reaction device 4, and a connector 10 made of insulating material is provided on the side wall section 11 of the discharge reaction device 4.

In addition, there is provided a rod shaped electrode 12 extending in a longitudinal direction of the discharge reaction device 4 inside the filter member 5.

On the other hand, the discharge generation device 7 is arranged on the outside of the discharge reaction device 4, and one electrode of this discharge generation device 7, for example, on a high voltage electrode side, is connected to the connector 10 via the electric cable 6. Further, the connector 10 and the electrode rod 12 are connected via the cable 6.

The other one electrode of the discharge generation device 7, on a grounding electrode side, is connected to side wall surface 11 of the discharge reaction device 4 via the electric cable 6 and it is grounded. That is, the inside wall surface 11 of the discharge reaction device 4 operates as the grounding electrode.

The discharge generation device 7 is constituted by, for instance, a primary source and a secondary source. The primary source is of AC power source of Φ 50Hz, 60Hz at AC100V, 200V, 400V, or DC power source of battery and the like at DC12V, 24V, and on the other hand, as the secondary power source, the pulse power source, high frequency power source and power-frequency AC power source may be used.

According to the structure mentioned above, when the voltage is applied from the discharge generation device 7, the electric field is caused towards the side wall surface 11 of the discharge reaction device 4 from the electrode rod 12 in the

filter member 5 of the discharge reaction device 4 and discharge plasma Y is also generated. The voltage application to the electrode rod 12 is of, for example, several kilovolts to few score kilovolts.

5 However, it is to be noted that polarity of the applied voltage from the discharge generation device 7, and shapes and number of the discharge reaction device 4, the filter member 5, and the electrode rod 12 are optional or arbitrary. In addition, an electrode may be arranged independently from the side wall
10 surface 11 of the discharge reaction device 4. That is, various structure may be adopted as far as the electric field and the discharge plasma Y could be caused or generated in the filter member 5.

 Moreover, it is possible to generate the discharge plasma
15 Y without heating the object gas X by being used as a low-temperature plasma with high electron temperature. The use of the low-temperature plasma permits the power applied to the discharge reaction device 4 to be utilized as the electron energy in the inside of the discharge reaction device 4, and the
20 power is not utilized as the thermal energy of neutral molecule and ion. As such low temperature, a temperature of less than 300°C will be preferably utilized in terms of catalyst activation. For this reason, the energy loss is reduced, the low power activates electron, and it is possible to generate larger number
25 of radical oxides.

 Further, the filter member 5 may have a structure in

which a plurality of ceramic pellets of solid material having spherical, columnar, cylindrical, or disc shape are filled up in a cylindrical or box-shaped and its opening is packed with a netting or a filter, or have a structure which is filled with fibrous material. The filter member 5 may be formed in honey-comb structure or in monolith structure.

In this regard, in the case of the discharge reaction device 4 having annular cylindrical structure and provided with the filter member 5, Fig. 2B is a sectional view of a structure utilizing a plurality of solid materials 5, Fig. 2C is a sectional view of a structure utilizing a fibrous material 5 and Fig. 2D is a sectional view of a honey-comb or monolith structure 5.

The gas purifying system 1 according to the first embodiment mentioned above will be operated in a manner described hereunder.

First, the object gas X, to be purified, containing the particular matter (PM) is generated in the object gas generating mechanism 2, and the generated object gas X is introduced to the discharge reaction device 4 through the gas flow line or path 3.

The object gas X flowing inside of the discharge reaction device 4 then passes the filter member 5.

In the filter member 5 within the discharge reaction device 4, the electric field is formed and the electric discharge plasma Y is generated in accordance with the operation of the

discharge generation device 7. Accordingly, the PM included in the object gas X to be purified is trapped in the filter member 5 in accordance with the electric collecting function of the electric field formed inside the filter member 5.

5 Further, in the inside section of the filter member 5, the radical oxides such as O, OH, O₃ and the like are generated in accordance with the operation or function of the discharge plasma Y. When the low-temperature plasma is generated as the discharge plasma Y, high energy electrons and molecules of
10 the object gas X collide with each other to thereby generate the radical oxides. Then, according to the operation of such radial oxide, the material such as carbon and the like included in the PM trapped by the filter member 5 is subjected to combustion treatment sequentially, resulting in the carbon
15 dioxide CO₂, so as to recover the PM trapping function of the filter member 5.

The object gas X after removing the PM is discharged externally of the discharge reaction device 4.

Incidentally, when the filter member 5 is constituted by
20 a dielectric substance having dielectric constant of more than 3, the electric field formed in the inside section of the discharge reaction device 4 is further stiffened, and it is possible to improve the electric collecting function and trapping efficiency of the PM. As a preferable example,
25 ceramics such as alumina having dielectric constant of 9-10 will be utilized in terms of heat resisting property.

On the other hand, in a case where the object gas X to be purified, which is discharged from the object gas generation mechanism 2, includes NO_x (90vol% of NO) or hydrocarbon (C_xH_y), the discharge reaction device 4 generates chemical species such as NO₂ which is generated through the oxidation of the radical oxide generated by the discharge plasma Y, and generates the partial oxidant [CHO] which is generated through the oxidation of the hydrocarbon through the operation of the radical oxide. These chemical species make it possible to decompose NO_x while performing reductive reaction efficiently between the chemical species and the NO_x included in the object gas X not only at high temperature but also at low temperature under the presence of reduction decomposition catalyst.

For this reason, in addition to the trapping and combustion treatment of the PM, the reduction decomposition of the NO_x can be performed without heating the NO_x by the use of the reduction decomposition catalyst corresponding to the chemical species generated inside the discharge reaction device 4 as the material of the filter member 5.

Incidentally, although the material of the filter member 5 is formed of the NO_x reduction decomposition catalyst, it is also preferable to carry the NO_x reduction decomposition catalyst with the filter member 5.

Fig. 3 is a diagram showing the NO_x reduction decomposition at the discharge reaction device 4 of the gas

purifying system 1 shown in Fig. 1.

With reference to Fig. 3, the NO_x included in the object gas X as an exhaust gas in which, generally, NO occupies 90vol% of the NO_x. Furthermore, in a case where the
5 hydrocarbon (C_xH_y) is further included in the object gas X, NO₂ and partial oxidant [CHO] are generated in which the NO and the C_xH_y are oxidized by the presence of the radical oxide generated by the discharge plasma Y in the discharge reaction device 4.

10 These chemical species generated in the discharge reaction device 4 operate as catalyst reaction activation species on the catalyst surface. The discharge reaction device 4 generates organic nitro compound [CHON] etc. from the NO₂ and [CHO]. Then, reaction between the [CHON] etc. and NO_x
15 (NO/NO₂) generates N₂, COX and H₂O, resulting in NO_x reduction decomposition.

As the reduction decomposition catalyst of the NO_x, for instance, γ -alumina may be provided. In the use of three way catalyst carried with noble metal such as Pt and the like
20 that are used conventionally as the reduction decomposition catalyst to the NO_x, harmful N₂O is generated in the decomposition of the NO_x. However, in the use of the γ -alumina, it is possible to reduce the NO₂ generation amount.

That is, in the conventional art, the three way catalyst
25 has been used to decompose the NO_x, and the three way catalyst carried with a noble metal such as Pt for the catalytic

activation. However, the gas purifying system 1 of the first embodiment of the present invention can perform the NOx reduction decomposition of not only at high temperature but also at normal temperature without using the noble metal such as Pt for activation, because the discharge reaction device 4 of the gas purifying system 1 generates the chemical species as the catalyst reaction activation species such as NO₂, and the partial oxidized substance ([CHO]) of the hydrocarbon and the like. For this reason, the gas purifying system 1 can reduce amount of the N₂O as by-product material generated at the time of the NOx reduction decomposition.

Fig. 4 is a graph representing relationship between lowering amount of NOx and temperature of the object gas X at a time of the reduction decomposition of the NOx included in the object gas X with 15 vol% content of oxygen O₂.

In Fig. 4, the axis of ordinate indicates the lowering amount (arbitrary unit) of the NOx, and the axis of abscissa indicates the temperature (°C) of the object gas to be purified. In the graph, symbol ● indicates data of NOx lowering curve showing lowering amount of NOx when performing reduction decomposition of the NOx by using the catalyst (γ-alumina) effective for NOx reduction decomposition at only a high temperature without providing noble metal, and symbol ○ indicates data of NOx lowering curves b, c and d showing the NOx lowering amount when performing the reduction decomposition of the NOx by the low-temperature plasma and

by using the reduction decomposition catalyst (γ -alumina catalyst) having a chemical species generated, as the reaction species, through the operation of the low-temperature plasma.

There are also shown the NO_x lowering curves b, c and d showing three types NO_x lowering amounts by changing electric energy of the low-temperature plasma.

As shown in Fig. 4, in the independent use of the catalyst (γ -alumina) effective for NO_x reduction decomposition at only a high temperature without providing noble metal, the lowering amount depends on the temperature of the object gas X in which a large inclination between the temperature and the lowering amount of the NO_x is indicated in a range of 300 to 500°C, and the lowering amount of the NO_x is remarkably reduced at not more than 300°C.

On the other hand, in the reduction decomposition method of the NO_x contained in the object gas X by low-temperature plasma and by using the reduction decomposition catalyst (γ -alumina catalyst) having a chemical species, as reaction species, generated by the low-temperature plasma and through the operation of the low-temperature plasma, the NO_x lowering amount depends on the temperature of the object gas X. However, the inclination between the temperature of the object gas X and the NO_x lowering amount becomes smaller than that in a case using only the catalyst. For this reason, it is possible to reduce a certain amount of NO_x at a low temperature not more than 200°C.

Further, in the NOx reduction decomposition method by using the low-temperature plasma and the reduction decomposition catalyst, the change of NOx lowering amount depends on the electric energy scale of the low-temperature plasma. That is, with increasing the electric energy of the low-temperature plasma, the NOx lowering amount increases. Therefore, it is possible to control the NOx lowering amount depending on NOx amount contained in the object gas X to be purified or temperature change.

Fig. 5 is a graph representing a relationship between the NOx lowering amount and the temperature of the object gas X to be purified at a time of performing the reduction decomposition of the NOx contained in the object gas X of 1 vol% content of oxygen O₂.

In Fig. 5, the axis or ordinate indicates the lowering amount (arbitrary unit) of the NOx and the axis of abscissa indicates the temperature (°C). In the graph, symbol ● indicates data of NOx lowering curve e showing lowering amount of NOx when performing reduction decomposition of the NOx included in the object gas X by using the conventional three way catalyst, and a symbol ○ indicates data of NOx lowering curves f showing NOx lowering amount when performing reduction decomposition of the NOx included in the object gas X by the low-temperature plasma and by using the reduction decomposition catalyst having the chemical species generated, as reaction species, through the operation of the

low-temperature plasma.

As shown in Fig. 5, as to the object gas X with 1 vol% oxygen O₂ content, the NO_x lowering amount depends on the temperature of the object gas X to be purified, and the large inclination between temperature and NO_x lowering amount is indicated in a range of 200°C to 400°C, which tends that the maximum value exists.

On the other hand, in the method for performing the reduction decomposition of the NO_x by the low-temperature plasma and the reduction decomposition catalyst, the NO_x amount can be reduced by a certain amount without depending on the temperature of the object gas X to be purified.

Fig. 6 is a graph representing a relationship between N₂O by-product amount and the temperature of the object gas X to be purified at a time of performing the reduction decomposition of NO_x included in the object gas X with 1 vol% oxygen O₂ content.

In Fig. 6, the axis of ordinate indicates N₂O by-product amount (arbitrary unit) and the axis of abscissa indicates temperature (°C) of the object gas X. In the graph, a symbol ● indicates data of N₂O lowering curve g showing the N₂O by-product amount when performing the reduction decomposition of the NO_x included in the object gas X by the conventional three way catalyst, and a symbol ○ indicates data of the N₂O lowering curves h showing the N₂O by-product amount when performing the reduction decomposition of the NO_x included in

the object gas X by the low-temperature discharge plasma and by using the reduction decomposition catalyst having the chemical species generated, as reaction species, through the operation of the low-temperature plasma.

5 As shown in Fig. 6, in the method for performing the reduction decomposition of the NO_x included in the object gas X by using the three way catalyst, the tendency substantially identical to that of Fig. 5 will be shown. That is, since the three way catalyst carries the noble metal such as Pt, the N₂O
10 is produced as by-product depending on the NO_x lowering amount.

On the other hand, in the method for performing the reduction decomposition of the NO_x by using the low-temperature plasma and the reduction decomposition catalyst,
15 the N₂O by-product amount tends to be lowered with increasing of the temperature of the object gas X. However, the changing amount of the N₂O by-product amount with respect to the temperature change of the object gas X is smaller than that in the case where the three way catalyst is
20 utilized, which is not more than 50% of the peak amount of the N₂O by-product amount in the case of utilizing three way catalyst.

That is, the gas purifying system 1 of this embodiment causes the electric field inside the filter member 5 so as to trap
25 the PM contained in the object gas X to be purified. Thus, according to the structure of the gas purifying system 1, the

PM can be trapped by the electric PM collecting function in addition to the PM trapping function of the filter member 5.

The gas purifying system 1 of the described embodiment reproduces the PM collecting function of the filter member 5 through the combustion treatment of the PM trapped by the filter member 5 without heating the PM by utilizing the electric discharge plasma Y without depending on the temperature.

Furthermore, the gas purifying system 1 achieves to remove the NO_x, from the object gas X, without heating the NO_x, while performing the reduction decomposition of the NO_x, as the chemical species generated from the hydrocarbon and NO_x in the discharge reaction chamber 4 as the reaction activation species by adding the function as the reduction decomposition catalyst to the filter member 5.

In these days, the discharge regulation concerning the discharge of NO_x or PM within exhaust gas from various engine sources has been made severe and strengthened. Because of this reason, recently, there has been proposed an apparatus, such as heater, for burning the PM with the heater while trapping the PM as a gas purifying system for removing the PM. On the other hand, there has also been proposed an apparatus for performing the reduction decomposition of NO_x, through heating, by using the three way catalyst carrying the noble metal such as Pt as the gas purifying system for removing the NO_x.

However, for these known gas purifying systems, it is

necessary to heat the object gas X up to at least not less than normal temperature, for instance not more than 200°C.

Particularly, when the gas purifying system is provided for an automobile and automobile exhaust gas is taken to as the

5 object gas X to be purified, it is difficult to sufficiently and stably deal with the PM or the NOx because the exhaust gas temperature is changed in accordance with the running or traveling conditions.

For example, as the exhaust gas temperature is lower
10 than temperature necessary for activation of the catalyst used for the PM burning or NOx reduction decomposition at the time of engine starting, engine low speed driving or engine accelerating, the decomposition reaction progresses not appreciably. For this reason, it has been necessary for the
15 gas purifying system to additionally be equipped with an external heating source.

Further, when performing the reduction decomposition of NOx, through heating, by using the three way catalyst, it was necessary to carry the noble metal such as Pt for the activation
20 of the three way catalyst, which, however, involves a problem that nitrogen monoxide (N₂O) is generated as by-product in the process of NOx reduction decomposition caused by the noble metal such as Pt.

However, the gas purifying system 1 of the present
25 invention permits the PM included in the object gas X to be subjected to the combustion treatment continuously with high

efficiency not only at high temperature but also at low temperature while trapping the PM with the filter member 5, by using the operation of the discharge plasma, that is hard to be subjected to influence of temperature change, or preferably, by using the low-temperature plasma.

Further, the NOx and the chemical species performing reductive reaction at a no high temperature are generated through the operation of the discharge plasma. Therefore, it becomes possible to perform the reduction decomposition of the NOx without heating, even at a low temperature, by constituting the filter member 5 using the NOx reduction decomposition catalyst.

Furthermore, according to the present invention, since it is not necessary for the gas purifying system 1 to use the noble metal for activating the NOx reduction decomposition catalyst, it becomes possible to reduce the generation amount of N₂O that is generated conventionally as a by-product at the time of the NOx reduction decomposition.

Accordingly, the gas purifying system 1 of this invention can purify the object gas X even in the use of various object gas generating mechanisms 2 which generate the object gas X including particular matter or harmful substance such as NOx and the like in accordance with the temperature change.

Fig. 7 is a schematic view showing a second embodiment of the gas purifying system according to the present invention.

The gas purifying system 1A shown in Fig. 7 is different from the gas purifying system 1 of the first embodiment shown in Fig. 1 in that the gas purifying system 1A is provided with an oxidation catalyst (oxidizing catalyst unit or section) 20
5 inside the discharge reaction device 4 in addition to the filter member 5. The gas purifying system 1A is substantially identical to that of the first embodiment in the other structures or functions. Therefore, the same reference numerals or symbols are added to the corresponding portions
10 and duplicated explanation is hence omitted.

The gas purifying system 1A of this second embodiment is provided with the oxidation catalyst 20 inside the discharge reaction device 4 in addition to the filter member 5 to be independently or to be provided for the filter member 5.

15 The structure of the gas purifying system 1A causes the PM trapped by the filter member 5 to be subjected to the combustion treatment in accordance with the operation or function of the oxidation catalyst 20 in addition to the radical oxide generated in accordance with the operation of the
20 discharge plasma. For this reason, the gas purifying system 1A is capable of performing the combustion treatment to the PM more efficiently than the gas purifying system 1 shown in Fig. 1.

Figs. 8, 9 and 10 are schematic views showing first,
25 second and third modified examples of the gas purifying system 1A shown in Fig. 7, respectively.

The gas purifying system 1B shown in Fig. 8 is provided with the oxidation catalyst (oxidizing unit or section) 20 on the way of the gas flow path or line 3 connecting the object gas generating mechanism 2 and the discharge reaction device 4.

5 That is, the oxidation catalyst 20 is located to the gas flow line 3 on the upstream side of the discharge reaction device 4 instead of installing the oxidation catalyst 20 inside the discharge reaction device 4.

Further, the gas purifying system 1C shown in Fig. 9 is
10 provided with the oxidation catalyst (oxidizing catalyst unit or section) 20 on the way of gas flow path 3 on the downstream side of the discharge reaction device 4 instead of installing the oxidation catalyst 20 inside the discharge reaction device 4 or on the upstream side thereof.

15 On the other hand, the gas purifying system 1D shown in Fig. 10 is provided with two oxidation catalysts (oxidizing catalyst units or sections) 20 for the object gas flow path 3, one being provided on the upstream side of the discharge reaction device 4 and the other one being provided on the
20 downstream side thereof.

As described above, the gas purifying systems 1B, 1C and 1D can attain substantially the same effects or functions as those of the gas purifying system 1 of Fig. 1, as far as the oxidation catalyst 20 structure is provided on the way of the
25 gas flow path 3 even if the oxidation catalyst 20 is not installed inside the discharge reaction device 4.

Furthermore in the gas purifying systems 1B, 1C and 1D, the oxidation catalyst 20 and the discharge reaction device 4 are disposed separately, so that it is possible to exchange only a required component or element without changing all the structure at the time of defective or repairs.

Fig. 11 is a schematic view showing a third embodiment of the gas purifying system according to the present invention.

The gas purifying system 1E shown in Fig. 11 is different from the gas purifying system 1 of the first embodiment shown in Fig. 1 in that the gas flow path 3 is branched before the arrangement of a plurality of discharge reaction devices 4, which are arranged in parallel.

The other structure and operation of the gas purifying system 1E has substantially the same as those of the gas purifying system 1 of the first embodiment shown in Fig. 1. Therefore, the same reference numerals or symbols are added to the corresponding members or elements and the detailed explanation thereof is omitted herein.

The gas purifying system 1E is provided with an upstream side switching element or section 30 for the gas flow path 3 on the upstream side of the discharge reaction devices 4, and the gas flow path 3 is branched at the switching section 30 in plural gas flow paths, for instance, two gas flow paths 3 as shown in Fig. 11. Each of the branched gas flow paths 3 is connected to each of the discharge reaction devices 4.

Further, the gas flow paths 3 for discharging the object

gas X passing through the respective discharge reaction devices 4 are introduced and collected to a common downstream side switching section 31 at which these branched exhaust gas flow paths are combined as a common single gas flow path 3.

The upstream side switching section 30 and the downstream side switching section 31 are switched so as to flow the object gas through one selected discharge reaction section 4.

That is, the gas purifying system 1E is capable of selecting one of the discharge reaction devices 4 through which the object gas X to be purified flows so as to switch the discharge reaction device 4 periodically in accordance with gas flow path switching function of the upstream side switching section 30 and the downstream side switching section 31.

According to the structure of this embodiment, the gas purifying system 1E is switched in operation at a time when the PM amount trapped by the filter member 5 of a certain discharge reaction device 4 reaches to the fixed amount, the flow of the object gas X is switched by the upstream side switching section 30, i.e. switching the gas flow path 3 to another branched gas flow path 3. In accordance with this switching operation, the downstream side switching section 31 will be also changed.

Furthermore, when the PM amount trapped by the filter member 5 reaches to the fixed amount, air containing PM of an

amount negligibly affecting the trapping amount of the PM is introduced to this one discharge reaction device 4. Then, the trapped PM in the filter member 5 is subjected to the combustion treatment by the low-temperature plasma generated from this air, and the PM trapping function can be recovered.

That is, one discharge reaction device 4 in which the PM is trapped by the filter member 5 is switched successively and alternately to the other discharge reaction device 4 in which the PM trapped by the filter member 5 is subjected to the combustion treatment by the low-temperature plasma.

More specifically, according to the gas purifying system 1E provided with a plurality of the discharge reaction devices 4 in which the gas flow path 3 through which the object gas X flows from the object gas generation mechanism 2 is branched into a plurality of paths in parallel by the upstream side switching section 30 and the downstream side switching section 31 so that the PM trapping function of the filter member 5 can be surely recovered by switching the respective discharge reaction devices 4 (i.e., branched flow paths) so that the PM amount trapped by the filter member 5 does not exceed the combustion treatment amount.

Moreover, according to the gas purifying system 1E, even if the concentration of the PM included in the object gas X to be purified is relatively large, it is possible to perform the combustion removal of the PM stably without lowering the PM

trapping function of the filter member 5.

The gas purifying system 1E may be capable of adopting a structure of no downstream side switching section 31 and, in this structure, the object gas X is discharged individually from the gas flow paths 3 connected to respective discharge reaction devices 4, or a structure in which the object gas X discharged from the respective discharge reaction devices 4 may be collected into single common gas flow path 3, directly.

Fig. 12 is a schematic view showing a fourth embodiment of the gas purifying system according to the present invention.

The gas purifying system 1F shown in Fig. 12 is different from the gas purifying system 1 according to the first embodiment shown in Fig. 1 in that the structure of the gas purifying system 1F is provided with a catalytic reaction section 40 in the gas flow path 3 on the downstream side of the discharge reaction device 4. Another structure and operation of the gas purifying system 1F has substantially the same as those of the gas purifying system 1 of the first embodiment shown in Fig. 1, and accordingly, the same reference numerals or symbols are added to the same or identical structures or elements with the detailed explanation thereof being omitted herein.

According to the structure of this embodiment, in which the gas purifying system 1F is provided with the catalytic reaction section 40 in the gas flow path 3 on the downstream side of the discharge reaction device 4, when the NO_x is

included in the object gas X to be purified discharged from the object gas generating mechanism 2, the discharge reaction device 4 causes the material of carbon and the like included in the PM to be subjected to the combustion treatment, and at the same time, chemical species such as NO₂, partial oxidant [CHO] of hydrocarbon and the like are generated.

Then, the NO_x reduction decomposition catalyst that attains catalytic activation function more strongly of the chemical species generated at the discharge reaction device 4 is filled in the catalytic reaction section 40. As to the catalyst filling the catalytic reaction section 40, for instance, γ -alumina accompanying no by-product of N₂O will be proposed.

The chemical species such as NO₂, partial oxidant [CHO] of the hydrocarbon and the like generated at the discharge reaction device 4 are introduced to the catalytic reaction section 40, in which these chemical species operate as the catalytic activation species, so that the NO_x is subjected to the reduction decomposition without heating.

Further, the object gas X, from which the reduced and decomposed NO_x is removed, is discharged outside the catalytic reaction section 40.

That is, the gas purifying system 1F of this embodiment is provided with the catalytic reaction section 40 provided with the NO_x reduction decomposition catalyst disposed on the downstream side of the discharge reaction device 4, in which the NO_x is subjected to the reduction decomposition to remove

the NOx from the object gas X by using the chemical species generated from the hydrocarbon and the NOx at the discharge reaction device 4 as the catalyst activation species of the NOx reduction decomposition catalyst.

5 According to this structure, the gas purifying system 1F is capable of obtaining the same effects and functions as those attained in the embodiment of Fig. 1, in which the NOx reduction decomposition catalyst function is added to the filter member 5. Thus, it becomes possible to perform inspection and
10 exchange individually in every structure.

Fig. 13 is a schematic view showing a fifth embodiment of the gas purifying system according to the present invention.

The gas purifying system 1G shown in Fig. 13 is different from the gas purifying system 1F of the fourth embodiment
15 shown in Fig. 12 in that the gas purifying system 1G is provided with a hydrocarbon adding (supplying) section or device 50 to the gas flow path 3 on the upstream side of the discharge reaction device 4. Another structures of the gas purifying system 1G is substantially the same as or identical to
20 that of the gas purifying system 1E according to the fourth embodiment shown in Fig. 12, and accordingly, the same reference numerals or symbols are added to the corresponding structures or elements and the detailed explanation thereof is omitted herein.

25 The gas purifying system 1G of this embodiment is provided with the hydrocarbon adding section 50 in the

upstream gas flow path 3 from the discharge reaction device 4.

The hydrocarbon adding section 50 supplies the hydrocarbon into the gas flow path 3. It is preferred to adopt a method of directly adding the hydrocarbon such as propane, propylene and the like, or a method for adding such gas-like hydrocarbon species such as propane, propylene and the like by once gasifying solid hydrocarbon species or liquid hydrocarbon species.

The thus added hydrocarbon species is introduced to the discharge reaction device 4, in which the catalyst activation species used for the NOx reduction decomposition is generated.

That is, according to the gas purifying system 1G of this embodiment, the NOx is decomposed and then removed while generating stable catalyst activation species more efficiently in the NOx reduction decomposition by adding the hydrocarbon species to the gas flow path 3.

Therefore, the gas purifying system 1G is capable of removing the NOx efficiently while generating the catalyst activation species, even though the object gas X is, for example, a gas, containing few amount of hydrocarbon, such as exhaust gas generated during lean combustion period of the diesel engine.

Fig. 14 is a schematic view showing a sixth embodiment of the gas purifying system according to the present invention.

The gas purifying system 1H shown in Fig. 14 is different from the gas purifying system 1A of the second embodiment

shown in Fig. 7 in that the gas purifying system 1H is provided with photocatalyst 60 instead of the oxidation catalyst 20 in the discharge reaction device 4. Another structure of the gas purifying system 1H is substantially the same as or identical to that of the gas purifying system 1A of the second embodiment shown in Fig. 7, and accordingly, the same reference numerals or symbols are added to the corresponding structures or elements.

The gas purifying system 1H is provided with photocatalyst 60 such as TiO_2 and the like in addition to the filter member 5 inside the discharge reaction device 4, the photocatalyst 60 being disposed independently or being carried by the filter member 5.

For this reason, when discharge light as well as discharge plasma Y is generated inside the discharge reaction device 4, the photocatalyst 60 is activated in accordance with the operation of the generated discharge light even in a case of a temperature in a low temperature region such as 200°C , as well as a high temperature, in the discharge reaction device 4.

That is, in the gas purifying system 1H, the PM trapped by the filter member 5 in the inside section of the discharge reaction device 4 is burned in accordance with the operation of the photocatalyst 60 activated through the operation of the discharge light in addition to the radical oxide generated through the operation of the discharge plasma.

Thus, the gas purifying system 1H is capable of

performing the combustion treatment of the PM more efficiently even in the case of the low temperature in the discharge reaction device 4, in addition to the advantageous effects of the gas purifying system 1A shown in Fig. 7.

5 Therefore, for example, in a case where the automobile exhaust gas, i.e. object gas X to be purified in this invention, has a low temperature, at an automobile engine starting time, it becomes possible to apply the gas purifying system 1H, making it possible to perform the combustion treatment of the
10 PM more efficiently.

 The gas purifying systems 1A, 1B, 1C, 1D, 1E, 1F, 1G and 1H of the structures mentioned above may be composed as multiple or composite structures. For example, the gas purifying system permits a plurality of discharge reaction
15 devices 4 to install in the gas flow path 3 in parallel. Further, there may be provided the catalytic reaction section 40, the hydrocarbon adding section 50 or the oxidation catalyst 20 in the gas flow path 3.

 Furthermore, as an alternation, it is preferred that the
20 discharge reaction device 4 may be constituted as one unit, and a plurality of such units may be arranged in parallel or in series so as to constitute the gas purifying systems 1A, 1B, 1C, 1D, 1E, 1F, 1G and 1H.

 It is to be noted that the present invention is not limited
25 to the embodiments described above and many other changes and modifications may be made without departing from the

scopes of the appended claims.